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Beech Utilization Series No. 3

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The Steam-Bending of Beech

by

Frederick F. Wangaard

Northeastern Technical Committee
On The Utilization Of Beech

in cooperation with

Northeastern Forest Experiment Station
Forest Service, U. S. Dept. of Agriculture

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FOREWORD

The wood of the American beech tree (Fagus grandifolia Ehrh.) is well suited for a large number of uses, and it is rather widely used by manufacturers. Yet the amount used is not in proportion to the amount that grows in our northeastern forests. The utilization of beech--both in the woods and in the factory--has been recognized as a problem.

One reason for this is in the nature of the wood: it has a reputation for being difficult to season. Another is that many of the beech trees in our forests are of poor quality. And there are some plain prejudices against beech.

Research is finding ways to utilize beech as efficiently as any of the other comparable hardwoods can be handled. Considerable information about beech has been gathered. Yet most of this information is available only in fragmentary form in scattered technical reports. Some of it has never been published.

To study the problems of putting beech to the uses it deserves, and to promote the better management of the forests in which it grows, a Northeastern Technical Committee on the Utilization of Beech was organized in 1949. This committee, which includes representatives of Federal and State forestry agencies, universities, and state experiment stations, decided to assemble and publish the available information about the utilization of American beech.

As its part of this cooperative project, the Northeastern Forest Experiment Station has undertaken to edit, publish, and distribute the series of reports that will contain this information.

The subjects of these reports will be as follows:

- * Physical and mechanical properties of American beech.

(CONTINUED ON INSIDE OF BACK COVER)

ACKNOWLEDGEMENTS

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THE STEAM-BENDING OF BEECH

by

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THE OLD ART of bending wood, following a softening or plasticizing treatment in steam or hot water, remains today the most economical and efficient means of producing wood members of curved form. Steam-bending is widely practiced in boatbuilding and in the manufacture of such products as furniture, chairs, handles, and sporting goods.

Beech is one of the relatively few woods that have been found particularly well adapted to bending. Because of its tendency to check on drying, the methods of treatment commonly employed with a number of other species, both before and after the actual bending operation, must be modified if best results are to be obtained with beech.

It is the purpose of this paper to clarify some of the problems encountered in bending and to promote a better understanding of the potentialities of beech in bent-wood products. In gathering the information upon which this paper is based, the available literature on bending has been consulted freely. The author also drew upon observation of factory operations and the practical experience of manufactures of furniture, athletic equipment, and other products made of beech.

PRINCIPLES OF STEAM-BENDING

Normal unheated wood can be bent to an appreciable curvature only in thin stock. A weakening effect is introduced when such wood is bent to a radius less than approximately 320 times its thickness and, if it is bent freely without support, fracture occurs at a radius of 50 to 80 times the thickness. Wood bent to a lesser degree, even though not ruptured, remains stressed in tension toward the convex face and in compression toward the concave surface. When unheated wood is bent, its elasticity tends to restore it to its original shape upon release from the external bending forces (12).¹

When wood is subjected to moist steam or to boiling water, its compressibility is greatly increased--as much as to 30 to 40 percent--although its ability to elongate under tension--about 1 or 2 percent--is not much affected (8). It thus becomes possible to bend steamed wood to relatively sharp curvature only if the required difference in length between the convex and concave surfaces can be achieved by holding the convex face relatively constant in length and restricting deformation almost entirely to a shortening under compression (6, 12, 15).

Moderate curvature (to a radius as short as 25 to 30 times the thickness of the stock) can be accomplished without restraining straps and end pressure. However, if a curve of shorter radius is desired, it is customary to employ a metal restraining strap on the convex surface, attaching it to the wood in such a way that only a limited amount of elongation can occur during the bending operation. Under such conditions it is possible to eliminate tension fractures and, with species that tolerate a great deal of compressive strain without developing localized centers of compression failure, to obtain bends having ratios of radius of curvature to thickness as low as $1\frac{1}{2}:1$. A further characteristic of steamed wood is that upon cooling and drying the bend "sets" and may be retained for many practical purposes upon release of restraint.

The principle of the restraining tension strap is illustrated in figure 1,A. Here the end stops attached to

¹NUMBERS IN PARENTHESES REFER TO LITERATURE CITED, PAGE 25.

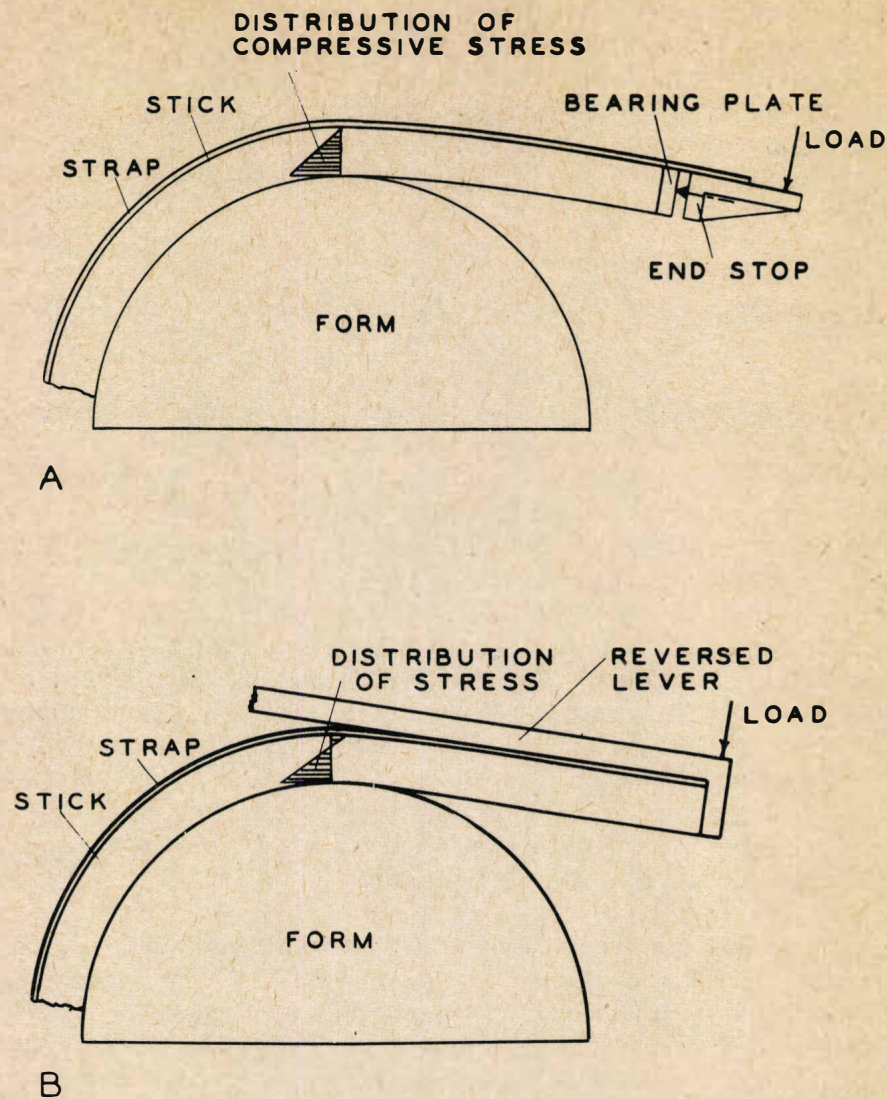


Figure 1.--These diagrams illustrate the principle of the tension strap used in bending wood. In A, end pressure is applied with a simple end stop. In B, end pressure is regulated by means of a reversed lever.

The differences in stress distribution are not inherent in the type of end stop. If absolutely no elongation occurs at the convex face, the stress is distributed as shown in A. But if limited elongation is permitted through partial release of end restraint, a stress pattern as shown in B will result.

the metal strap prevent elongation and thus limit all bending stress to compression, which is at a maximum at the concave face. The application of pressure on the convex surface of the piece during bending to prevent reverse bending and end crushing through avoidance of excessive end pressure is illustrated by the reversed lever in figure 1,B.

PREPARATION OF WOOD FOR BENDING

Insofar as the bending operation alone is concerned, successful bends can be made over a wide range in moisture content; but most satisfactory results are probably obtained at moisture contents near the fiber-saturation point, or approximately 25 to 30 percent. Green wood may contain so much moisture that hydrostatic pressures developed in bending may cause wrinkles to occur at the concave face of the bend (6). On the other hand, wood that has been dried to a low moisture content is too stiff to bend well without excessive steaming. A further consideration involves the problem of drying the stock, after it has been bent, to a moisture content consistent with its ultimate use. Consequently it is usually advisable to season wood before steaming to a moisture content in the neighborhood of 25 percent and, in some cases, to as low as 12 percent.

Whenever possible, stock to be bent should be machined to approximate final shape and size so that, if necessary at all, operations following the setting and drying of the bend may be limited to sanding. Of course, this is not always possible, and machining operations that are sometimes awkward on bent stock may then be necessary. Surfacing prior to bending serves the additional function of removing saw marks and other irregularities that may induce compression failures on bending.

Both heat and moisture are essential to satisfactory softening or plasticizing of wood in preparation for bending. Treatment with steam or hot water is the best practical means devised for this purpose, although various chemical aids have been tried (4, 6). Experimental steaming has been tried at pressures higher than atmospheric, but there appears to be no advantage to such procedures and, in fact, the higher temperatures may be detrimental to the wood.

Exposure to saturated steam at atmospheric pressure

in a closed retort or steam box is the method most commonly used to soften wood. The steam should be introduced through water standing in the bottom of the retort, or other means should be provided to assure its saturation.

The duration of the steaming period will vary with thickness and moisture content of the stock and with the severity of curvature involved, but as a general rule green stock should be steamed approximately $\frac{1}{2}$ -hour and dry stock about 1 hour per inch of thickness (6). The additional period required for dry stock results from the need not only for heating but also for the addition of moisture to the surface zones.

Treatment by immersion in boiling water is essentially equivalent to steaming for a comparable period and is employed to advantage when only a portion of a piece is to be bent, as in certain types of chair posts and tool handles.

METHODS OF BENDING

Free Bending

Free bending, that is bending without the use of a restraining strap, is successful only when relatively slight curvature is involved--specifically when the difference in length of convex and concave surfaces measured by the ratio

$$\frac{\text{thickness of stock}}{\text{radius of curvature of convex surface}}$$

does not exceed approximately 3 to 4 percent. Probably the simplest means of bending wood is to force a stick about pegs fixed to a backplate; or to clamp one end of the piece to a male form and bend the piece to the shape of the form, wedging it at the opposite end of the bend.

Such bends may also be made in a hot-press equipped with shaped platens and steam-heated to temperatures approximating 250°F., as is frequently done in the forming of chair backs. Where more severe curvature is involved, the stock may be pressed in a bending pan that provides for end pressure (16). Retention of shape is secured by retaining the bend in the press until it is dry. Free bends are also employed in boatbuilding when steamed members are cramped

into position and held in shape by attachment to a rigid structure. Another method of bending that does not employ end restraint--the intrusion method--involves forcing a straight piece through a curved mold (9, 11).

None of these methods is adapted to bending to sharp curvature without a substantial percentage of failures.

Restraining Straps

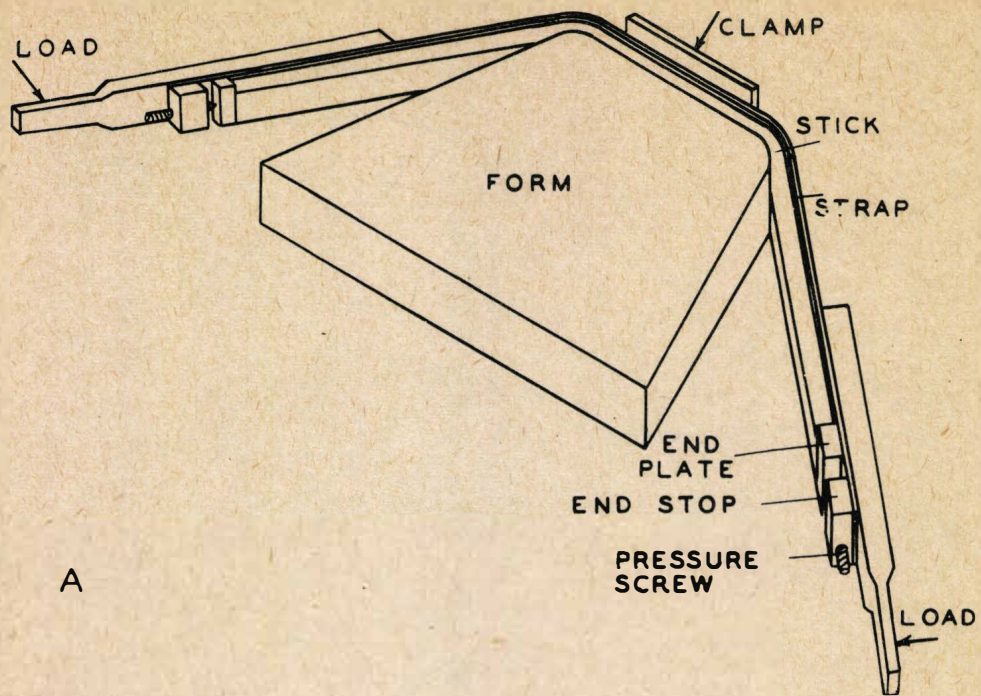
In contrast to free-bending methods are those that involve end pressure applied through restraining straps (2). Numerous hand-bending and machine-bending devices employ this principle, many of them also incorporating the reversed lever. The more complicated bends are usually made by hand by skilled workmen. Hand-bending methods may also be advantageous when only a limited number of bent pieces of a specific shape are desired.

Simple bends about a form can be made by hand, employing a mild or spring steel strap at the convex face of the bend and attaching the strap by means of end stops (6, 10). A brass strap is frequently used where discoloration of the wood from a steel strap is to be avoided. The strap should be at least as wide as the stick, and slightly-tapered wedges or end screws used to draw it tight.

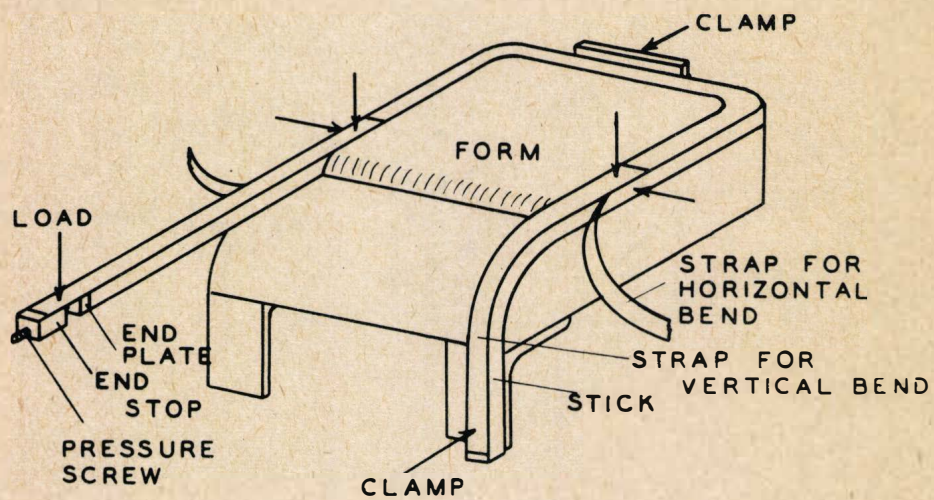
The piece is usually clamped to the form at the middle of the bend and the two halves are bent to the form by hand (fig. 2,A). A skilled operator applies pressure as needed to the convex side of the bend to avoid reverse bending in the uncompleted portion of the bend. Upon completion of the bend, the curved piece is held to shape by attaching a wood stay lath across its ends. Then it is removed from the form. The operation is accomplished within a few minutes after removal from the steam box.

Should the bend be so severe that fractures would occur at the convex face upon release of end pressure, the strap may be retained on the bend. The bend and strap may then be removed as a unit from the form. A bend of complicated shape may have to be retained on the form until set.

Straps with adjustable end stops to permit control of end pressure throughout the bending operation are especially suitable when long pieces of small cross section are being bent (10). Controlled release of end pressure helps to over-



A



B

Figure 2.--Methods of hand-bending wood. *A*, forming a simple bend by using a tension strap fitted with adjustable end stops. *B*, forming a bend that involves successive curvature in two planes.

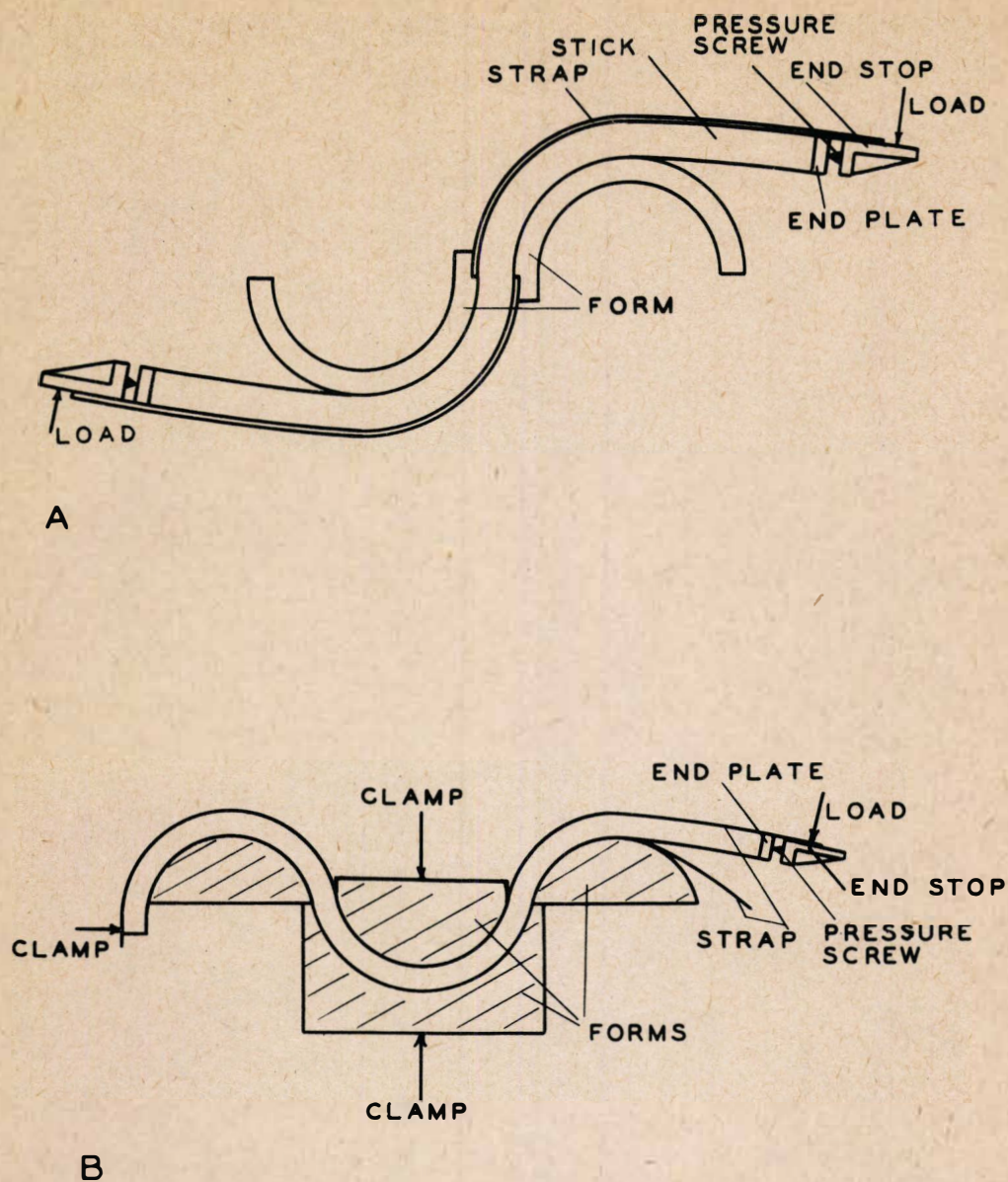


Figure 3.--Methods of bending S-type and re-entrant type curves. A, an S-type bend employing a tension strap attached to each form. B, a re-entrant type bend formed through the use of two full-length tension straps with the central part of the stick clamped in place after completion of that part of the bend.

come the tendency for reverse bends arising from longitudinal pressure. Such release should not exceed 1 to 2 percent of the bent length (12, 17). Clamps may be used to prevent lateral bending at intermediate points.

When bends involve successive curvature in two planes (fig. 2,B), a strap arrangement is required that will restrain elongation at the convex surface of any curved portion of the member. The first part of such a bend is made in normal fashion, clamped in place, and the clamped-on end stops are removed. In the bend shown in figure 2,B, two additional straps attached in a plane at right angles to the main strap are next fitted to the remaining length and attached to the stick by means of end stops. The final portion of the bend is then completed in a plane at right angles to the initial bend. The finished bend is usually retained on the form for setting. Stock of round cross-sectional shape can be bent through use of a single flexible strap which is twisted about the piece, always covering the convex face (10).

S-bends may be made by using two forms placed in correct position and attaching to each a strap fitted with an end stop as shown in figure 3,A. Two full-length straps, one on each face of the piece, may also be used successively (fig. 3,B). As a portion of the bend is completed, it is held in place by forms and the end stops are removed; then the remainder of the piece is bent in the opposite direction.

Bending Machines

Bending machines are usually of either the lever-arm or revolving-form type (6, 9). In the lever-arm type machine (fig. 4,A) the steamed piece a is fitted with a slightly overlength minor strap b on the face that will be convex in the bent member and placed against a fixed form c. A major strap d attached to movable arms e is fitted with end stops which are adjusted to the exact length of the piece to be bent. After clamping the stick to the form at the mid-point of curvature, the bend is produced through action of the movable arms, which are powered to force the piece against the form. These arms are arranged so as to bear progressively on the wood near the point that is being brought into contact with the form. If necessary, a slight elongation of the piece during the bending operation can be permitted through controlled release of end pressure by screw adjustment of the end blocks attached to the major

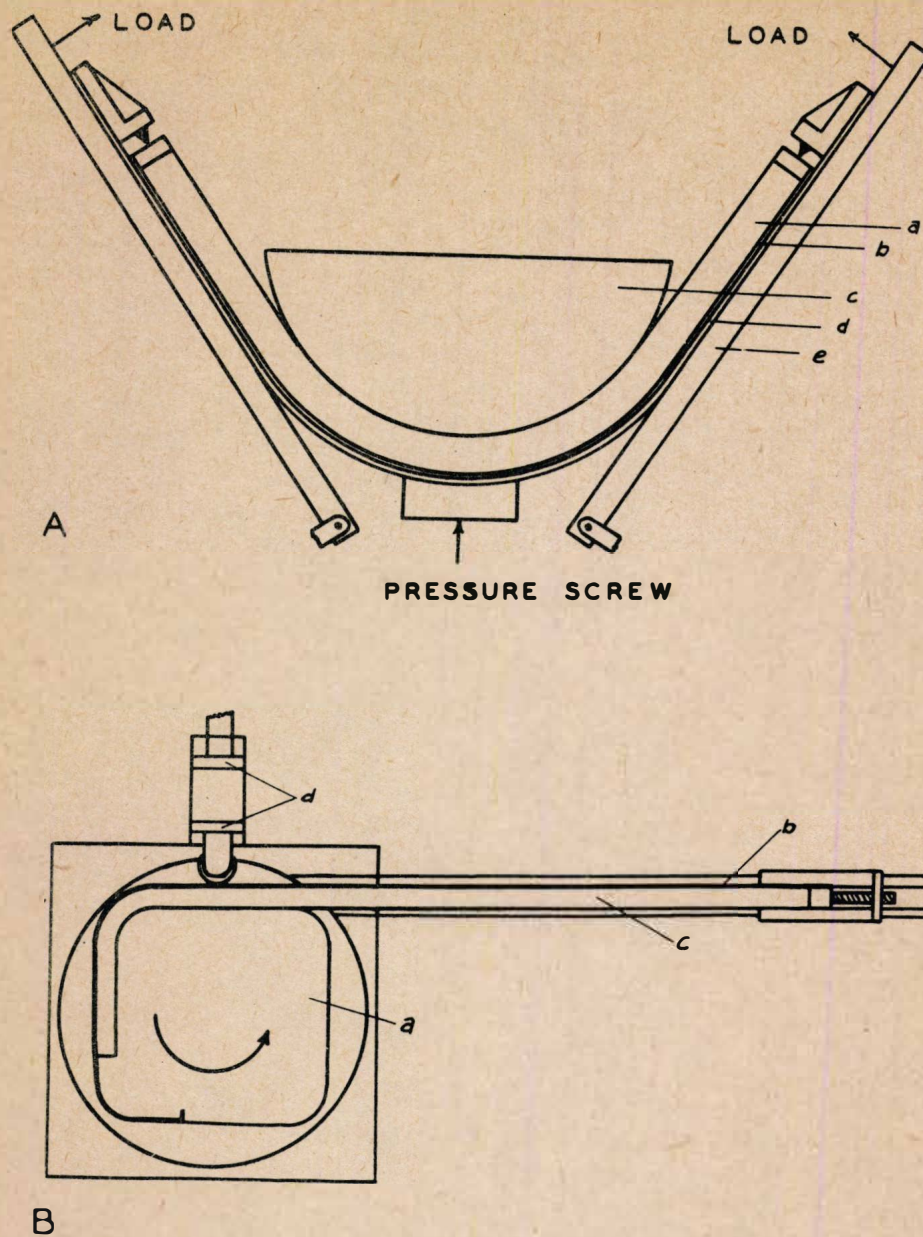


Figure 4.--Bending machines. A, a lever-arm machine showing the bent piece (a), minor strap (b), fixed form (c), major strap (d), and movable arms (e). B, a revolving-form machine showing form (a), tension strap with end stops (b), bent piece (c), and piston (d).

strap. After completion of the bend, a tie rod is placed across the ends of the minor strap and; upon retraction of the lever arms, the bend and its minor strap are removed for setting. Several bends can often be made simultaneously through the use of wide straps.

With such equipment, bends are limited to a maximum angle of approximately 180° in one direction. This type of machine is also generally limited to forming bends of continuous curvature such as chair backs or rockers.

Members that involve both straight and curved sections are usually produced more satisfactorily on machines of the revolving-form type. A revolving-form machine (fig. 4,B) consists of a suitably shaped form a mounted on a revolving bed (9). A tension strap with end stops b is attached to the wood c and one end of the wood is clamped to the form. The bend is produced by the rotation of the bed; this automatically wraps the piece about the form. Pressure applied by means of a hydraulic piston d or spring-loaded roller is advantageous in bringing the bend into close contact with the form. Regulated release of end pressure during the bending operation is possible through screw adjustment of the end stop. This type of machine is adapted to all types of bends that can be made by lever-arm devices and, in addition, bends greater than 180° can be produced readily. For a bend of continuous uniform curvature the piece and its strap may be removed from the form when held to shape with a tie rod. When the member consists of straight and curved sections, it is clamped on the form, and the form, bend, and strap are removed from the machine as a unit. Among the bends made on this type of machine are table boxings and ring seats for chairs.

SETTING OF THE BEND

A bent piece will partially straighten when released from restraint while still hot and moist. An insufficiently set bend of sharp curvature (relative to its thickness) is also apt to fail in tension upon removal of the restraining strap while still held to the curved shape. To overcome these faults, steam-bent pieces are usually set by holding them, together with tension straps and tie rods, in a heated room until they are dry.

Setting does not require drying, but merely cooling, if its objective is simply to hold approximately to a curved shape without rupture. However, bent members are subject to changes in shape with moisture-content variations and should be held to shape until dried to the approximate moisture content encountered most frequently in subsequent service. In the case of mild bends the tendency to spring back is not completely overcome even after drying, and such bends are often intentionally bent somewhat excessively to compensate for this anticipated spring-back (6).

Bent members are sometimes dried under ordinary atmospheric conditions without restraining straps as in the case of boat-framing members, which are customarily dried in place on the vessel. In furniture and chair factories, bent members in straps (and sometimes on forms) are often permitted to dry slowly under shop conditions.

If straps are removed before drying, bends ordinarily should not be set at temperatures above 100°F. (10). When straps are kept in place, however, bends are often dried in humidity-controlled chambers maintained at 140° to 190°F. and, with some species, at temperatures as high as 250°F.-- in which case no control of humidity is possible. The protection provided by straps and end stops is undoubtedly helpful in avoiding checks and splits under these conditions. Bends made in hot presses are retained in the press until dry, usually at temperatures of 250° to 260°F. Regardless of the method of drying, the bend should be held to its desired shape until reduced to a moisture content suitable for ultimate service.

BENDING CHARACTERISTICS OF BEECH

In spite of the rather extensive use of beech in commercial bending over a long period and its generally favorable reputation as a bending wood, relatively little specific information is available in the literature to supplement commercial experience. European beech has enjoyed an especially favorable reputation for its excellent bending characteristics, although preferences have been noted for material grown in certain geographic areas, specifically the British Isles and the Carpathian Mountains of eastern Europe.

European Beech

The Forest Products Research Laboratory in England has rated a large number of woods on the basis of experimental bending of carefully selected defect-free specimens, both with and without restraint (3). Using as a criterion the minimum radius to which 1-inch pieces could be bent without exceeding 5 percent breakage, European beech grown in the British Isles was successfully bent to a $1\frac{1}{2}$ -inch radius when tension straps were employed.

On this basis European beech was rated as a "very good" bending wood, equivalent to rock elm, black locust, Japanese oak, and sycamore maple, and surpassed only by white oak (1-inch radius) and Dutch elm ($\frac{1}{2}$ -inch radius). Other "very good" species (which, however, were not quite so good as British-grown European beech) included American elm, Wych elm, European oak, imported European beech (4-inch radius), European ash, and American ash. According to Peck (6), the following American woods of good bending quality may be rated in descending order: American elm, white oak, black locust, beech, yellow birch, and red oak.

Without end pressure, 1-inch sticks of European beech (British-grown) were successfully bent to a 13-inch radius, comparable to American ash, white oak, and European oak. European beech (British-grown) was exceeded only by Dutch elm, black locust, European ash, Japanese oak, and Wych elm, and was followed by such woods as American elm, rock elm, European beech (imported), sycamore maple, and European basswood.

American Beech

The U.S. Forest Products Laboratory (6) has rated the following better bending woods in order of descending quality on the basis of percentage of breakage in a uniform bending test without end pressure: hackberry, white oak, red oak, chestnut oak, magnolia, pecan, black walnut, hickory, beech, American elm, willow, birch, ash, sweetgum, soft maple, yellow-poplar, and hard maple.

From these comparisons it may be concluded that beech is among the most satisfactory of bending woods, particularly when end restraint is employed. It also appears that American beech, while it may be somewhat less adaptable to bending than the best European beech, is not appreciably

different from the average of European beech that has been so widely used in bent-wood products. This is substantiated by the practical commercial experience of furniture manufacturers.

One American manufacturer reports the successful bending of Adirondack-grown beech to a 3- to 4-inch radius, using 3/4-inch stock and tension straps. Another states that breakage was prohibitive in hand-bending (with strap pressure) 4/4-inch beech to a radius smaller than 12 inches. But according to the same manufacturer, much better results were obtained when bending operations were performed on machines--because of the more uniform control of end and side pressure. Comparative tests led this manufacturer to the conclusion that slow-grown beech is superior in bending quality to faster-grown wood. However, specific data are not available to substantiate this conclusion. Manufacturers rather generally prefer sap beech to heartwood.

Bending Tests At Yale

In a limited series of bending tests conducted at Yale University (1), two methods of evaluating bending quality were employed. One of these was based on a visual estimate of quality. One-inch defect-free stock at 20 to 30 percent moisture content was steamed and bent to an 8-inch radius using a restraining strap (removed upon completion of the bend) and holding the unrestrained specimen to shape with a stay lath attached across its ends. A rating of "excellent" was used for pieces in which compression failures were inconspicuous; those with evident compression failures extending less than half the depth of the specimen were designated as "good"; those with prominent compression failures extending from mid-depth up to 1/8 inch from the convex face were rated "fair"; others which showed either tension failures or compression failures extending throughout their entire depth were rated "poor."

From two shipments of beech originating in Coopers-town, N. Y., and Harrisburg, Pa., 24 specimens were bent to an 8-inch radius. Of these, 9 rated "excellent," 10 "good", and 5 "fair." A few white oak specimens bent under comparable conditions were rated "excellent." When bent to a 6-inch radius, most of the beech specimens were rated "fair," and those bent to a 10-inch radius were rated "excellent."

The second method of evaluation of bending quality was based upon results of a strength test after the bend had been set and dried. In a static-bending test, patterned after a method used at the U. S. Forest Products Laboratory (5), maximum fiber stress sustained by the bent stick when loaded on the convex face as a beam was compared with the modulus of rupture of straight unsteamed specimens of matched material. Any reduction from modulus of rupture values for straight beams is indicative of the damaging effect of the bending process.

The average loss in strength of all 1-inch beech stock which had been bent to an 8-inch radius was 32.1 percent. (The comparative figure for white oak was 26.1 percent.) "Excellent" beech bends of 8-inch radius showed an average loss of 27.8 percent; "good" bends lost 31.7 percent, and "fair" bends lost 38.6 percent. In bends to a 6-inch radius, strength loss averaged 36.2 percent, while at a 10-inch radius the average strength loss was only 14.8 percent. In these tests no significant influence of specific gravity or of sapwood vs. heartwood was found, although admittedly the data are too limited to be conclusive.

The foregoing results support other evidence that beech is a very satisfactory bending wood and only slightly surpassed in this respect by white oak. Oak is, of course, well recognized and widely used for its excellent steam-bending qualities. White ash, elm, and hickory are similarly employed. Because of its finer and more uniform texture, however, beech is not apt to be used interchangeably with these species wherever appearance is a factor. The evaluation of beech as a bending wood is therefore of greatest practical value when it is compared with such woods as yellow birch and hard maple, and on this basis beech is readily recognized as possessing superior bending qualities.

Entirely independent of bending quality but, nevertheless, factors which cannot be overlooked in the evaluation of beech as a bending wood are the problems of seasoning lumber prior to bending and of drying the set bend. In fact, the satisfactory solution of the checking problem may well be regarded as the key to successful bending of beech.

RECOMMENDED PRACTICE

IN BENDING AND DRYING BEECH

Because of the inherent tendency of beech to check upon drying, particular care is required in the handling of logs and lumber prior to steaming or boiling.² Losses as high as 50 percent in bending beech, attributable largely to checking, have been reported in commercial operations where methods adapted to the processing of birch and maple were used without modification. The checking of beech sticks during the drying period following bending poses another serious problem.

In principle, the most practical solution appears to be to carefully control drying during the preparatory period to bring the stock virtually check-free to the lowest moisture content compatible with the degree of curvature desired. For bends of a radius equivalent to 6 to 8 inches or less for 1-inch stock, this probably will involve drying only to 20 to 25 percent moisture content. Where atmospheric conditions do not permit air-seasoning of beech to such moisture contents without harmful checking, resort should be made either to chemical seasoning or to drying under the temperature- and humidity-controlled conditions of a kiln. For less severe bends, seasoning to moisture contents as low as 12 to 15 percent, preferably under controlled mild drying conditions in a dry-kiln, is suggested in order to minimize later difficulties during the subsequent drying of the bend. It is, of course, entirely possible to steam and bend green stock fresh from the log if facilities for slow, controlled drying of the bent stock are available.

Insofar as selection of material suitable for bending is concerned, beech is no different from any other wood. For severe bends stock should be straight-grained (a slope of grain steeper than 1 in 15 is considered excessive) and free of all knots, localized grain irregularities, decay, or comparable defects (6). It has been clearly demonstrated that even pin knots, which would be insignificant for most uses, may introduce serious buckling at the compression face in steam-bent members (7). At the other extreme, short moderate bends for such items as chair backs are commonly made

²THE PROBLEMS OF STORING AND SEASONING BEECH TO MINIMIZE CHECKING ARE DISCUSSED IN OTHER PAPERS IN THIS SERIES.

from ordinary factory cuttings of No. 2 Common grade lumber.

The steaming or boiling periods specified for wood in general are applicable to beech; i.e., $\frac{1}{2}$ hour per inch of thickness for green wood and 1 hour per inch for wood that has been dried to 12 to 15 percent moisture content. All of the bending methods described in this paper are applicable to beech.

As with other woods, bends of beech that are dried following removal of straps should be dried slowly at temperatures below 100°F. When straps are retained on tension surfaces, however, and end stops protect the end surfaces of the stock, beech may be dried successfully in heated chambers at temperatures up to 150° or 160°F., particularly if relative humidity is controlled to regulate rate of drying. Green beech bends 1-inch thick have been successfully dried in 16 hours, and air-dry stock in 12 hours under such conditions (10). Thicker stock may require several days of drying. Under certain conditions somewhat lower temperatures may be necessary to avoid checking and splitting.

PROPERTIES OF BENT WOOD

Steam-bent wood that has been fixed and dried changes in curvature with subsequent variations in moisture content. As a result of changes in thickness and shrinking or swelling of the upset wood toward the concave face of the piece, the bend tends to straighten at high humidities and to increase in curvature at low humidities. However, the changes induced by swelling are not completely reversible, and after a cycle of wetting and drying the bend fails to recover its original shape. Consequently a bent piece of wood retains its curvature only when maintained at a constant moisture content or when held in shape by attachment to other members of a rigid structure. Hence the need for holding the bend by means of straps and tie rods or on forms until dried to approximately the moisture content that the wood will have in its ultimate use.

After fixing and drying, the strength of bent wood is lower than that of normal wood at the same moisture content. For the better bending woods, at least, such loss of strength is attributable to the over-stressing that occurred in bending and not to the plasticizing effect of the steam-

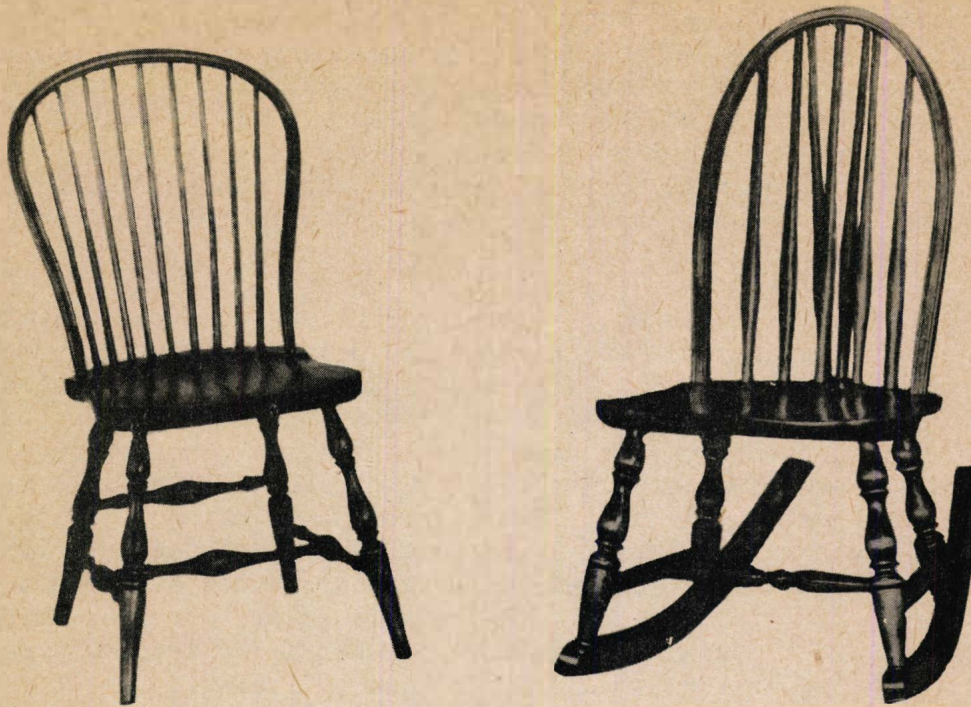


Figure 5.--Colonial windsor chairs for which beech is frequently used in top bow and rockers.

ing treatment, which is only temporary. At a radius 140 times the thickness of the bent stick, practically no strength loss in either static- or impact-bending occurs in the case of good bending wood, even when loaded so that the concave (upset) face is stressed in tension (17). As bends increase in severity, however, the strength loss becomes appreciable. Losses in static-bending strength (concave face stressed tension) for 1-inch beech were previously referred to. When bent to a 10-inch radius, strength loss averaged 14.8 percent; at 8 inches loss was 32.1 percent; and at 6 inches 36.2 percent. These losses are due primarily to weakening at the concave face and are greatly reduced if only the portion of the bend toward the convex face is considered.

Similar tests reported by Wilson (17) on portions of a bent wheel rim showed that whereas the full section developed a modulus of rupture of 8,000 pounds per square inch, smaller sections representing the inner and outer halves of the bend developed values of 7,300 and 12,400 pounds per

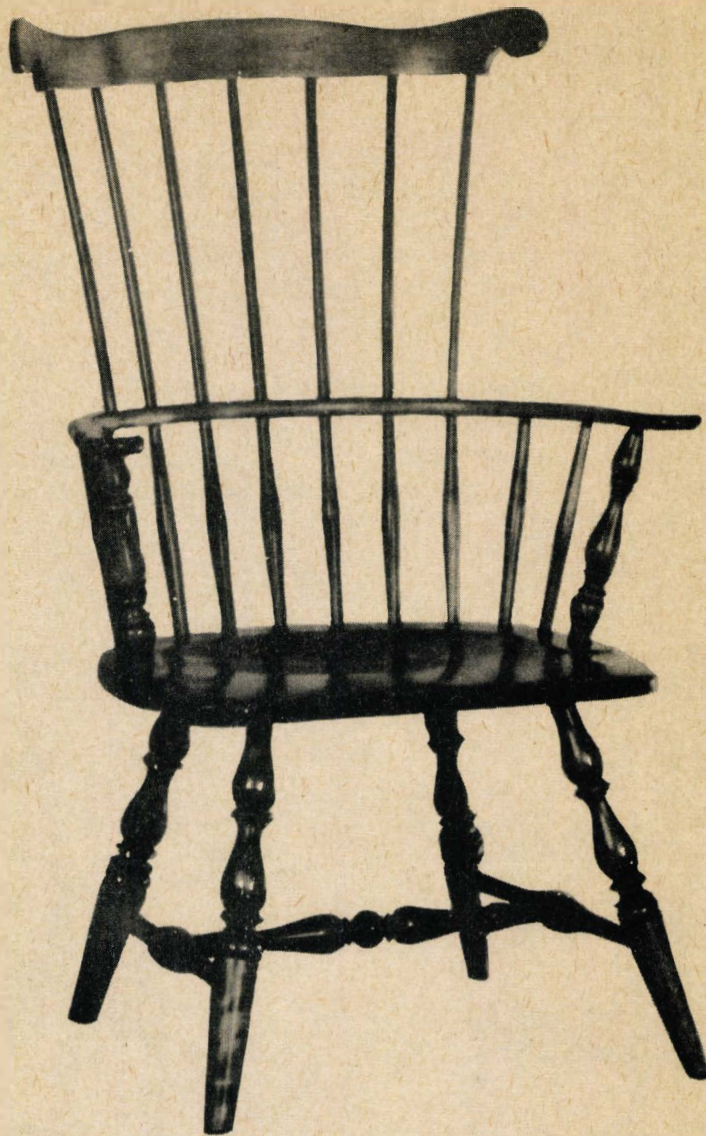


Figure 6.--Comb-back windsor chair with back and arm bow of beech.

square inch respectively. It is evident that the efficiency (strength-weight ratio) of a bent stick is greatly improved if the wood toward the concave surface is subsequently removed by machining.

BEECH BENT-WOOD PRODUCTS

The principal use of beech in bent form is in furniture, particularly in chairs. Colonial windsor chairs of the patterns shown in figure 5 are frequently made of beech, maple, or birch. In these chairs the top bows and rockers are steam-bent. The comb-back windsor chair pictured in figure 6 has a back and arm bow of bent beech. The posts of Hitchcock and ladder-back chairs are often made of steam-bent beech, although many manufacturers have turned to birch or maple because of their greater tolerance for rapid drying.

These graceful colonial designs that made such effective use of steam-bent members were augmented in the latter part of the 19th century by light bent-wood chairs that had their origin in Austria. Possibly such designs reflected the feeling that much of the massive furniture of that period was greatly oversize and very wasteful of a dwindling

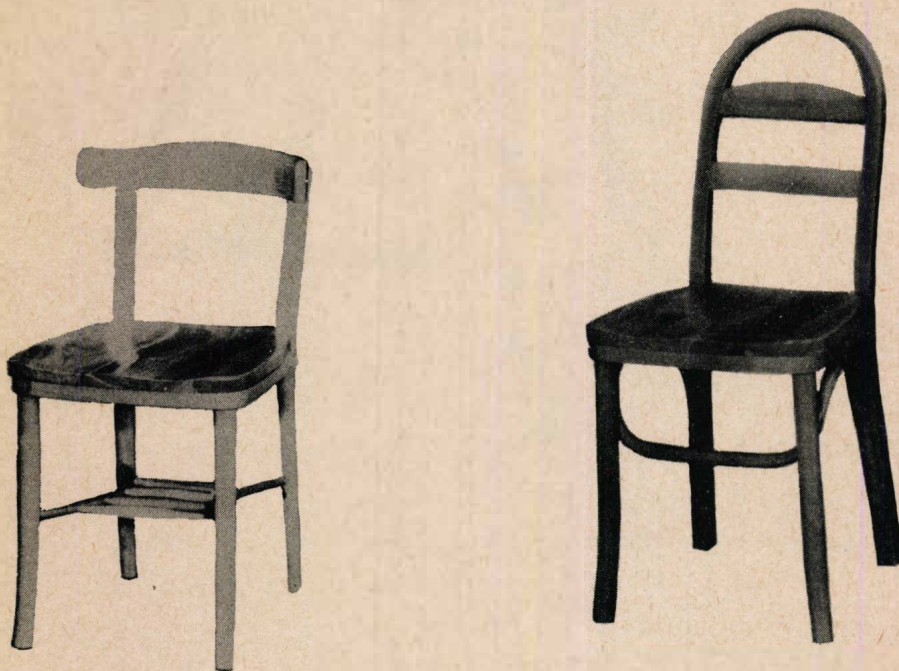


Figure 7.--New York bent-wood chairs in which steam-bent beech is commonly employed in seat framing, backs, and bracing.

timber resource. At any rate there is little question but that the Austrian type of bent-wood chair represents an extremely efficient use of wood through the almost exclusive employment of steam bends in bows, legs, bracing, and seat frames. An American modification of this type, known as New York bent-wood, is shown in figure 7, which pictures chairs of a type widely used in schools and cafeterias. Steam-bent beech is employed in such chairs in the form of seat framing, backs, and wish-bone braces. A circular seat frame of beech is shown on its bending form in figure 8,A and an unfinished arm bow for a windsor chair in figure 8,B.

Bent beech has its use in modern living-room furniture too. Beech was used extensively in many of the modern bent-wood designs of the 1930s (fig. 9, left) in both chairs and tables. If properly handled to avoid checking, beech is well adapted for use in modern living-room items of current



Figure 9.--Uses of bent wood in modern chair design. Left, design popular in the 1930s. Right, a modern upholstered chair, for the bent-wood arms of which beech is well adapted.

manufacture (fig. 9, right) for which sap birch is now in much demand.

Other uses for steam-bent beech include such sporting-goods items as tennis racket and squash racket frames and

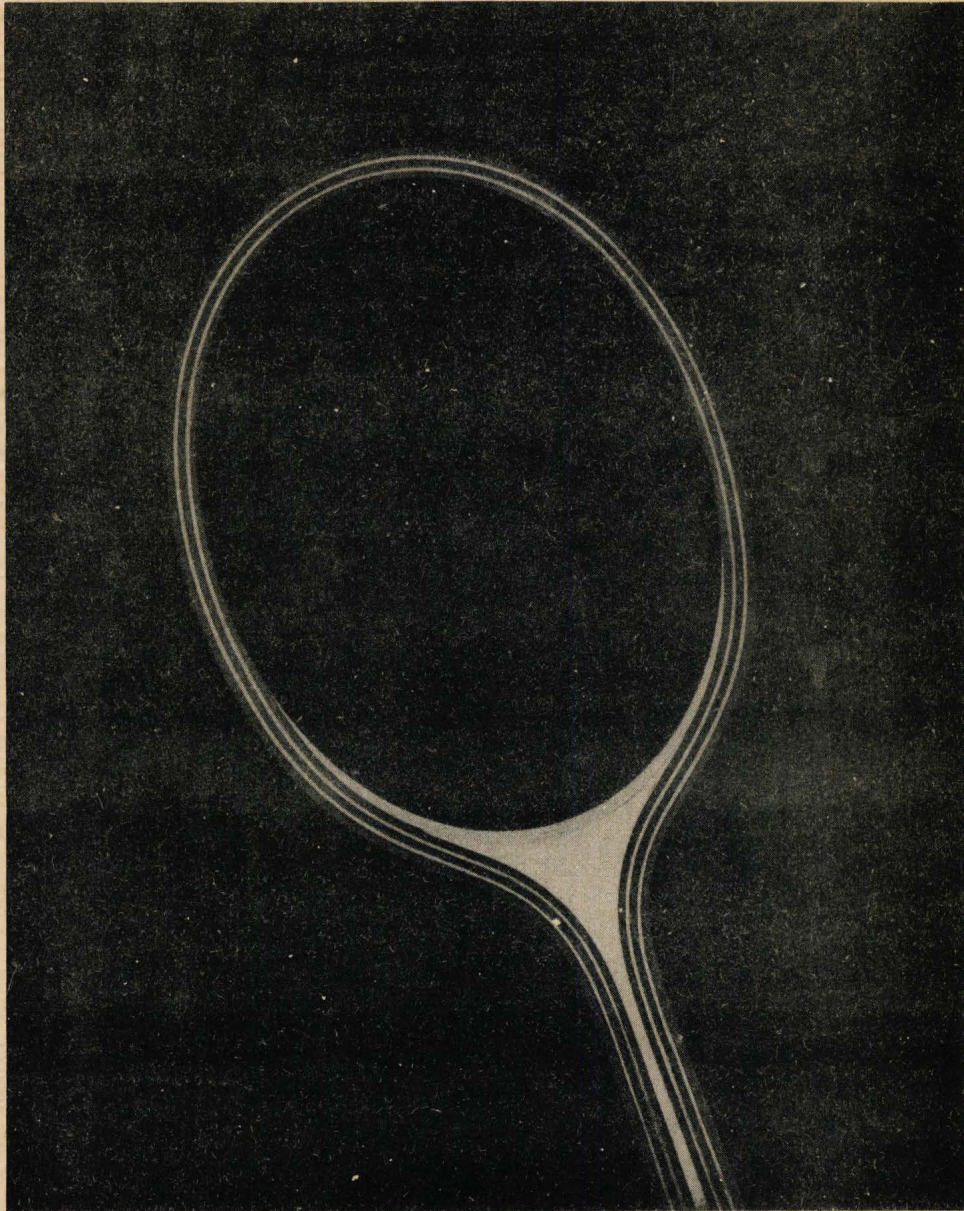


Figure 10.--Steam-bent tennis-racket frame, made up from laminations of beech and white ash.

hockey sticks. A laminated tennis racket frame employing steam-bent beech is shown in figure 10.

The bending qualities of beech are well adapted for these purposes and are complemented by its many desirable strength properties--including resilience, hardness, and abrasion resistance. In many types of curved handles for tools and implements, steam-bent beech is either used at present or its potential use may be anticipated where maple or birch are currently employed satisfactorily. Beech lacks the degree of shock resistance that is usually required in bends that are subjected to severe impact loading and for which rock elm or hickory are commonly employed. The use of beech in bent members in boatbuilding appears to offer some possibility of replacing scarce bending oak, provided suitable means of seasoning and drying of bends to avoid excessive checking can be assured. Where, as in boat hulls, a decay hazard is associated with the conditions of use, beech requires preservative treatment.

An interesting scheme for the employment of beech in bending, as yet undeveloped in commercial practice, has recently been proposed in England (13, 14). By the prior gluing of a thin layer (1/16-inch) of European beech to what later becomes the compression face of a bend, a combination 1-inch thick of beech and an otherwise desirable wood lacking good bending qualities can be steam-bent to a radius as small as one-third of that possible for the poor bending wood alone. The potentialities of this technique may be of particular interest in connection with furniture items in which only the wood of attractive figure on the convex face of the bend is exposed.

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* Storage of beech logs and bolts.
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Beech for furniture.
Beech for turned products and novelties.
Beech for veneer and plywood.
Beech for fuel and charcoal.
Beech for cross ties.
Beech for containers.
Pulping and defiberization of beech.
Rough construction on the farm with beech.

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The information gathered in this widespread cooperative project should be of great use to the wood-using industries of the regions where the wood of American beech is available.

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